Revue Médico-Pharmaceutique. Année 1. Nos. 1–3. 4to. *Constantinople* 1888. The Editors.

Symons's Monthly Meteorological Magazine. December, 1886. 8vo. *London.* Mr. G. J. Symons, F.R.S.

Three Autograph Letters of Sir Joseph Banks, P.R.S. Mr. J. W. L. Glaisher, F.R.S.

May 28, 1888.

Professor G. G. STOKES, D.C.L., President, in the Chair.

The Croonian Lecture—"Ueber die Entstehung der Vitalen Bewegung"—was delivered by Professor W. Kühne, of Heidelberg, in the Theatre of the Royal Institution.

[Publication deferred.]

May 31, 1888.

Professor G. G. STOKES, D.C.L., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

Mr. George King (elected 1887) was admitted into the Society.

Pursuant to notice, Professors Edmond Becquerel, Hermann Kopp, Eduard F. W. Pflüger, and Julius Sachs were balloted for and elected Foreign Members of the Society.

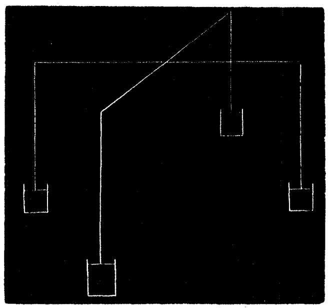
The following Papers were read:—

I. "On the Effect of Occluded Gases on the Thermo-electric Properties of Bodies, and on their Resistances; also on the Thermo-electric and other Properties of Graphite and Carbon." By JAMES MONCKMAN, D.Sc. Communicated by Professor J. J. THOMSON, F.R.S. Received May 1, 1888.

"Le Roux has shown that when a notch is filed into a wire and one side heated there is in general a thermo-electric current. He also found that when two wires of the same metal, with flat ends, are

pressed together, so that one forms a continuation of the other, and the wire on one side of the junction is heated, no current is obtained, but he observed a current in all cases where there was dyssymmetry." When repeating these experiments, I was led to commence a research on the effect of occluded gas by the following curious phenomenon. Two pieces of platinum wire of 0·9 mm. section, and of 925 mm. length, were stretched with weights only just heavy enough to keep them straight. They were placed at right angles to each other, the centres being in contact, and the ends bending down into mercury cups (see fig. 1). Each wire after being carefully annealed was joined up to a

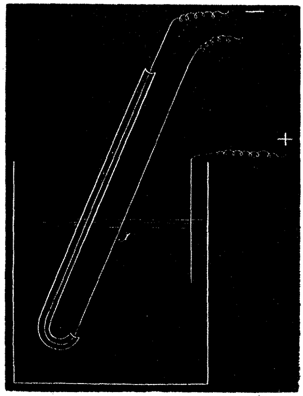
FIG. 1.



galvanometer, and the absence of currents from strain proved by heating with a small flame. When both wires were found to be perfectly free, they were brought together in the middle, and one end of each connected with the galvanometer. On heating the wires near the point of contact thermo-electric currents were produced, but after heating the junction of the wires to a bright red for a little time and allowing it to cool, the currents produced by heating the wires on either side were opposite in direction to those produced before. After resting from Saturday until Monday the change in the wires, produced by heating the point of contact, was found to have disappeared, and the currents produced by heating the wires to be the same as at first.

This naturally suggesting that some kind of temporary change took place in the wire, when heated in a Bunsen lamp, and that this might possibly be produced by the gas absorbed by the platinum at a high temperature, I was induced to commence a series of experiments on the effect of occluded gases on the electrical properties of bodies. A piece of platinum wire about 18 inches long was bent in the middle, and one-half protected by being covered with glass tube and made water-tight at the lower end. After annealing the free portion and testing until perfectly free from all strain effects, it was placed,

Fig. 2.



up to about the middle, in acidulated water, and made the negative pole of a battery, and hydrogen liberated upon it for a few minutes. After being dried it was tested with a small flame at distances of 1 cm. along its whole length. The result was a current from the free wire towards that part on which hydrogen had been produced, greatest at the junction of the free wire and the saturated wire.

	H.	Free wire.
The deflections were......	0. 0. 0. 7. 10.	10. 7. 4. 1. 0.
Another experiment gave..	0. 0. 5. 5. 5. 8.	8. 5. 5. 0. 0. 0.

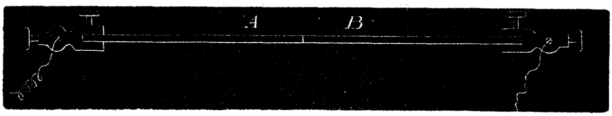
When wires of palladium were used more powerful effects of the same kind were produced. Thus when two wires were used as the electrodes in decomposing acidulated water, dried and gently heated in contact, a current towards the hydrogen was observed. If heated by a Bunsen flame complications arose from the hydrogen in the wire taking fire. The flame produced could easily be seen 4 or 5 mm. away from the Bunsen flame.

Carbon rods were next tried. Gas-carbon was first tried, but I was unable to get two rods sufficiently similar in composition to be of use, their own thermo-electric currents being large enough to cover all changes produced by gases. I had, however, no difficulty in getting rods made for arc lamps to answer my purpose. They were heated to a red heat to expel gases, and the ends were filed flat.

It was found that when one of these rods was heated and placed against the other (see fig. 3), the current was always from cold to hot below 200° C.

They were then used as the electrodes in decomposing dilute sulphuric acid, dried carefully until no current was produced on placing

FIG. 3.



them in contact. On heating either rod and joining them as before, a current was produced from hydrogen to oxygen across the hot junction.

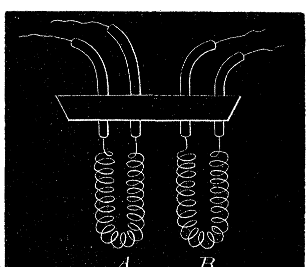
The same effect was obtained by decomposing hydrochloric acid solution, in which case we get chlorine instead of oxygen, and the current flows from hydrogen and chlorine.

If the rod be saturated with SO_2 it is found to act like those containing oxygen or chlorine.

Resistance.—In the first experiments made to try if any change of resistance took place when wires are saturated with gas, a platinum wire about a yard in length was formed into a spiral, and each end soldered to an insulated copper wire. The junctions were covered with wax, and the wires, carefully insulated with wax, passed through two holes in a cork into a bottle containing dilute sulphuric acid. Through the same cork there passed a thermometer and two glass tubes. The whole was placed in a large vessel of water. After having saturated the wire with hydrogen, the acid was drawn off, and air drawn through for some time. The resistance was found to increase slightly on testing.

To get rid of possible error from change of temperature, two wires of equal length and section were used and balanced against each other (see fig. 4).

FIG. 4.



These were placed in water, and a current passed from the one to the other, allowed to remain in the acid a little to cool if necessary, and afterwards removed, dried, and placed in an empty glass vessel surrounded with a considerable quantity of water. There they rested until the temperature became the same as the water. When measured

the resistance of the wire containing the hydrogen was found to have increased about one-thousandth part. It is not necessary to try the effect of hydrogen on palladium, as the resistance is known to be increased considerably by the absorbed gas.

Carbon.—Two thin rods about 2 mm. diameter were electroplated at the ends and soldered to insulated copper wires. After protecting the plated portion with marine glue, the whole was fixed to a convenient frame, and placed in dilute sulphuric acid. As was done in the case of the platinum wires, the rods were balanced against each other in order to eliminate changes of temperature, &c.

When used as the poles of a battery the change of resistance was considerable, but greater on the rod that had been the positive pole. By using a platinum electrode, hydrogen or oxygen was produced at will upon the same rod, the other rod remaining unchanged. It then appeared that oxygen increased the resistance much more than hydrogen, rising in some cases as high as nine times; that when oxygen was liberated twice or thrice in succession, the resistance increased each time. This continued increase was probably due to chemical changes produced by the active oxygen. Hydrogen gave an increase of resistance, not continuing beyond a certain point, and not becoming greater on repeated charging with the gas.

Generally also the effect of the hydrogen was temporary, disappearing, wholly in some cases, partially in others, when short circuited.

The following series of observations afford an example of this :—

1. When rod A was charged with oxygen its resistance was	4·15	ohms.
2. When rod A was charged with hydrogen its resistance was	4·1633	,,
3. When rod A was charged with hydrogen its resistance was	4·1633	,,
4. When rod A was charged with oxygen its resistance was	4·2833	,,
5. When rod A was charged with oxygen its resistance was	4·2966	,,
6. When rod A was charged with hydrogen its resistance was	4·3099	,,
7. Allowed to rest short circuited	4·2966	,,
8. Again charged with hydrogen	4·3066	,,
9. Allowed to rest	4·303	,,

In the case of hydrogen, the increase was 0·0133 ohm in two experiments, and 0·01 in the other, while it recovered completely after observation No. 6 and partially after No. 8.

Superposition of Polarisations.—Part of the change in the carbon is evidently produced by the mechanical action of the gases evolved,

and by the chemical action of the oxygen; both of these will, however, produce permanent changes. That only part of the action is to be explained in this way is shown by the previous experiments. It is, however, further demonstrated by using two carbon rods in decomposing acidulated water; after passing the current for one minute, reverse it for one-tenth of a second and immediately join up to a galvanometer. A short but violent deflection appears for the latter contact, gradually falling to zero and passing to the other side, where it remains for a considerable time, though with much decreased quantity.

The same thing was obtained with platinum electrodes. The second contact must be very short, or the former polarisation disappears. I have not yet succeeded in obtaining more than one reversal, although I have no doubt that more may be got with very thick electrodes.

Resistance.—Copper and iron absorb hydrogen and silver occludes oxygen, but no change in their thermo-electric properties could be detected. Carbonic oxide is absorbed by iron, and is said to produce great changes in its properties. In this case, however, only the resistance was measured.

A piece of iron wire, about 3 yards in length, was twisted into a spiral and placed in a porcelain tube; the ends projecting about 3 inches, were connected with one side of a bridge and balanced against an equal spiral of the same wire. After exhausting the tube about 1 foot of the central portion was heated to a bright redness and then allowed to cool. Next day the resistance was measured, and the experiment repeated twice. On the third heating, carbonic oxide was allowed to enter the porcelain tube, and readings of the resistance taken on cooling as before. This was also repeated.

This series was again repeated with new wires, and lastly, the wire was raised to a bright red *in vacuo* and allowed to cool, the object being to remove the carbonic oxide gas in order that another measurement might be taken after these repeated heatings. The resistance fell, clearly proving that part of the previous increase was due to the presence of the gas. No measurement of resistance was taken on the same day that the wires were heated, but at least 15 hours were allowed to elapse.

First series of observations give the numbers thus:—

Average of three measurements after heating *in vacuo*, 0·4 ohm.
" " " " in carbonic oxide, 0·41 "

With the new wire—

Average of three measurements after heating *in vacuo*, 0·63 "
" " " " in carbonic oxide, 0·655 "
After heating *in vacuo* to expel the gas, it fell to 0·642 "

These experiments appear to prove that absorbed gases increase the resistance of conductors, and that hydrogen renders metals more negative (thermo-electrically) whilst carbon becomes more positive.

I have introduced the experiment (fig. 1) which caused this work to be undertaken, although I do not think that it is entirely caused by the occlusion of gases, where the best results are obtained by electrolysis which produces them in a nascent or more energetic state.

Thermo-electric and other Properties of Graphite and Carbon.

In making the previous experiments, I had occasion to place the heated end of one carbon rod in contact with the cold end of another. The temperature of the hot end was varied from 30° C. to a red heat, whilst the cold end was kept at about 17° C.

Currents of electricity were of course produced. When the temperature of the hotter rod was raised but slightly, the current was from cold to hot through the point of contact, but when it was raised to a red heat the current passed from hot to cold; between these temperatures the direction of the current varied, appearing at first sight to obey no rule, and as nothing was known that would explain these results, I was led to examine the matter more carefully.

There were several difficulties to be overcome before any satisfactory results could be obtained.

Firstly, it was necessary to get two rods of such pure material, that they would not produce a current when placed in contact end to end and heated, or at any rate weak enough to be neglected in presence of that produced by the contact of the two rods at different temperatures.

I tried several specimens of gas-carbon, but as no two pieces were found to fulfil the condition before mentioned, they were useless. I was more fortunate with the rods prepared for arc lamps in electric lighting, readily finding two that answered my purpose.

A small portion of one of them gave on combustion less than one part of incombustible matter in 200 of carbon. They were heated repeatedly to a red heat and allowed to cool slowly. The ends were filed flat to prevent difference of shape producing any current.

When placed in contact end to end and heated, one rod was slightly positive to the other, but not sufficiently to prevent the experiments from succeeding.

Secondly, the manner of making contact caused the currents to vary much in strength, and the surface of the heated rod required filing at intervals, in order to preserve a clean flat face.

It was found also that the heat of the hot rod passed so quickly to the cold one that even after a very short contact the current fell, so that the rods could be placed together once only and for a very short

time; after which they require to be brought back to their original temperature.

Lastly, to avoid any possible effect from the coal-gas, the end to be heated was inclosed in an iron tube lined with asbestos.

The temperatures were measured in various ways. In some experiments an ordinary thermometer was used for temperatures below 250° C.; thermo-electric couples of platinum and copper, silver and copper, were tried, but, although much more tedious, I found the method of platinum wire much less liable to error.

The wire was given to me by Mr. H. F. Callendar, M.A., and was from the same piece as that used by him in his experiments on "The Practical Measurement of Temperature" (see 'Phil. Trans.,' vol. 178 (1887), p. 161).

The following equations for this wire were used in determining the temperature, and are those obtained by Mr. Callendar in his experiments:—

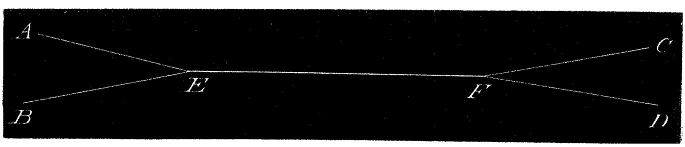
$$\frac{R^t}{R^0} = 1 + 0{\cdot}00346\,\mathrm{Pt}^\circ.$$

$$t^\circ - \mathrm{Pt}^\circ = 1{\cdot}57\left\{\left(\frac{t}{100}\right)^2 - \frac{t}{100}\right\}.$$

R^t = resistance of the platinum wire at t° C.
R^0 = ,, ,, ,, 0° C.

The wire was arranged as in fig. 5, by which means the resistance of

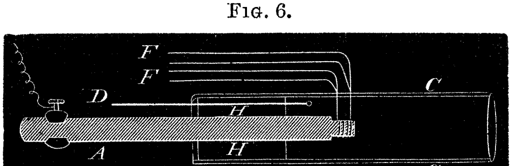
Fig. 5.



EF alone could be obtained by observing those of AC, BD, CD, and AB; also AB and CD were known if required, which indeed was the case of one of the later experiments.

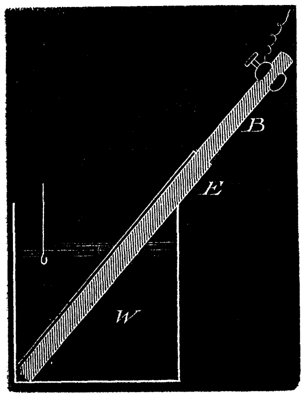
In some cases the insulation was thin tubes of hard glass, in others the wire was wrapped up in thin sheet asbestos. The arrangement is shown in figs. 6 and 6*a*, where A and B are the carbon rods, C an

Fig. 6.



iron tube lined with sheet asbestos, H, H packing of asbestos, D a thermometer for moderate temperature and to test the calculations

FIG. 6*a*.



from the platinum wire, F, F platinum wire insulated; W a vessel of water containing a brass tube E, closed at one end, in which the carbon rod B is placed after each contact.

During the first series of experiments the temperature of W, and hence of B, was 16° C., that of A was changed in each contact, rising to 480° C. and higher. At about 480° the deflection changed; decreasing on approaching that temperature, and changing sign above it. I am sorry to say that the difficulty of obtaining the same perfection in each contact was so great that the deflections, although increasing above 480°, were not sufficiently consistent to allow a curve to be drawn.

Therefore, assuming that the neutral point was midway between that of the two rods when no current was produced (*i.e.*, 16° C. and 480° C.) we get 248° C. for the temperature of that point.

B being kept in the second series at 50°, in the third at 100°, and in the fourth at 200°, and the same assumption made in the calculation as before, 255° C. was given as the neutral point. If we now rule a line such that any two points being taken in it, the current shall be equal to the vertical distance between them, and shall flow from the higher point to the lower, it will have its lowest point at from 248° to 255°, rising to 0° and 480° and above (see fig. 7). This assumes that the two lines are equally inclined, and from the experiment with a platinum-carbon couple we judge them to be so, and their turning point to be 250° C.

From the preceding experiments I was led to expect that the line of carbon in a thermo-electric diagram, in which the area of the space between the lines is proportional to the electromotive force, would show a bend of some kind, and as no researches were known showing such a bend, it appeared desirable to test it carefully.

There is a paper by E. Becquerel in which he gives an account of a

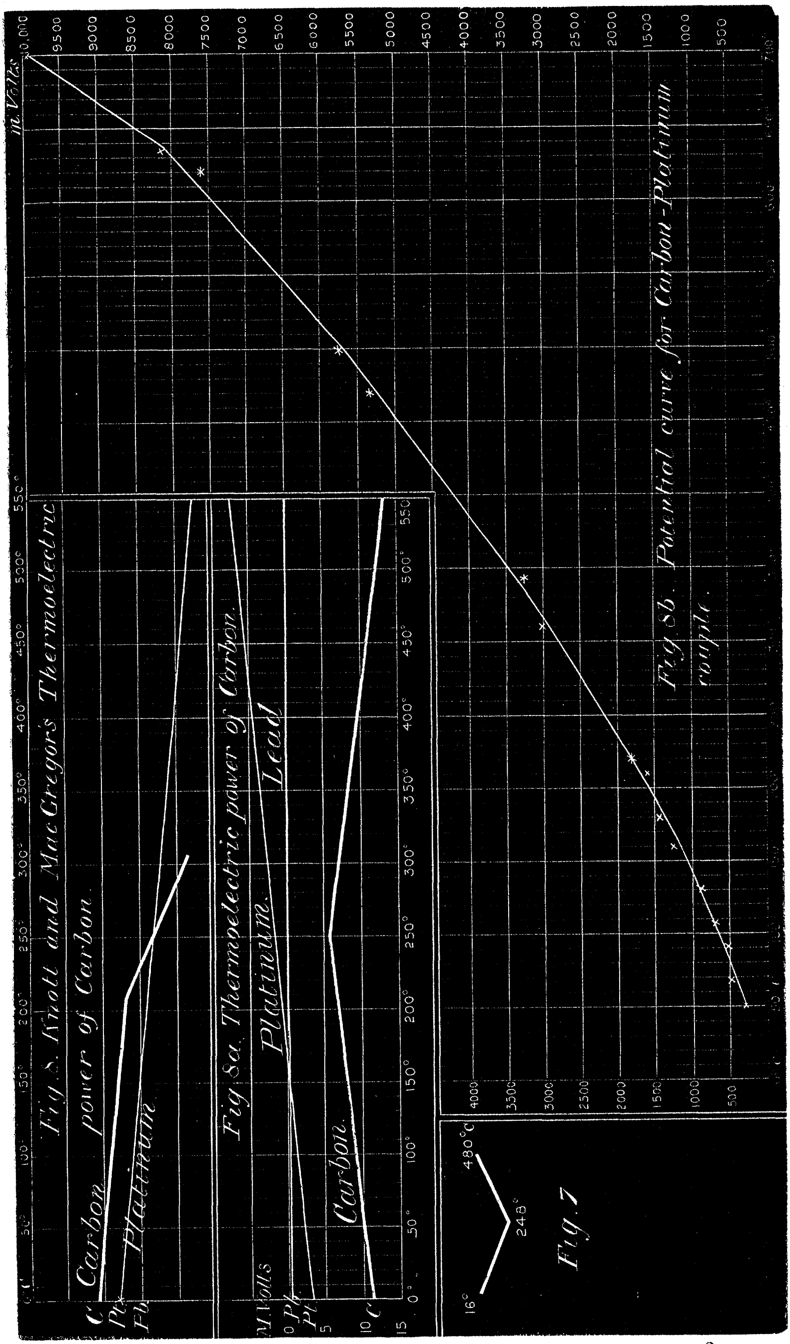


Fig. 8. Knott and MacGregor's Thermoelectric power of Carbon.

Fig 8a. Thermoelectric power of Carbon.

Fig 8b. Potential curve for Carbon-Platinum couple.

Fig. 7

number of experiments with various bodies, among which is gas-carbon. The hot junction was 100° C., at which temperature the deflection produced by a couple (carbon and copper) was negative, the same as copper-platinum, but a little larger. He does not appear to have worked at higher temperatures ('Annales de Chimie,' vol. 8, 1866, p. 415).

Knott and MacGregor also worked with gas-carbon, and in 1879 published a paper in the 'Transactions of the Royal Society of Edinburgh,' vol. 28, in which a line for carbon is given. The material was in the form of a cylinder 15 cm. long, 1·5 cm. thick. A strong heated wrought-iron tube, 4 inches long, 2 inches diameter, and 1-inch bore, closed at one end, was suspended over the junction and allowed to cool gradually.

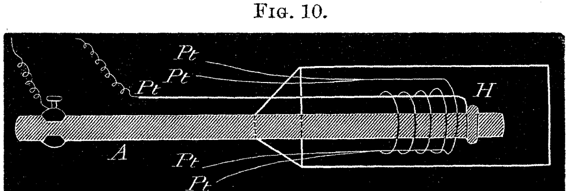
From 230° downwards the line is parallel to that of platinum. Above 230° it appears somewhat uncertain; they speak of it thus:—"For a small range of temperature (to 230° C.) it is possible to express the deflection in terms of the first and second powers of the temperature, the following formula holding good: $\delta = -8{\cdot}29 + 0{\cdot}604\,t + 0{\cdot}000385\,t^2$; above 230° C. it does not, perhaps because of chemical changes, produced by heat. Carbon appears to be an exception to the general law." "The above formula and the graphic treatment enable us at a higher temperature to determine its position" (see fig. 8). The position and slope of the lines are opposite to those now used.

Such a result did not appear to agree with the experiments already described, and as I had found gas-carbon a very unsuitable body for use where two pieces were required having anything like the same thermo-electric power, it appeared probable that good results might be got with the other rods; and as carbon and platinum form for 230° parallel lines I decided to use a couple consisting of these two bodies.

Nine series of observations were taken, using three different methods, of which it will be sufficient to describe the last.

Near one end of a carbon rod a hole, about 5 mm. in diameter, was drilled, and into this the end of a platinum wire was inserted and fixed by being wedged with a piece of rod carbon. The whole was thoroughly covered with Indian ink, which, when dry, was again

FIG. 10.



covered with clay. The carbon rod was insulated from the platinum wires, and they from each other by thin sheet asbestos and mica, by which means it was insulated from the vessel in which it was placed, and luted with clay to prevent access of air (fig. 10). The numbers obtained in three series are—

Expt. 1.		Expt. 2.		Expt. 3.	
t.	E. in micro-volts.	*t.*	E.	*t.*	E.
50	270	220	1800	210	1620
70	450	344	3240	312	3024
88	540	499	5760	471	5292
107	720	620	7560	635	8154
130	900	700	9900	722	9990
160	1260				
180	1440				
210	1620				

The colder junction was at 17° C.

The resistance of the Pt-C couple was found to vary, increasing to 600°, after which it decreased. This result being caused by the increased resistance of the platinum being partly neutralised by the diminution of the resistance of the carbon, to which must be added the improved contact obtained by the expansion of the platinum in the carbon, which is greater than the expansion of the carbon, thence the pressure increases and the contact improves.

The numbers were at 220° C. 0·88 ohm, 340° to 500° C. 0·92 ohm, 620° C. 1·03, 700° C. 1·00.

These experiments agree perfectly with the diagram given by Knott and Macgregor (fig. 8) as far as they carried it experimentally. When, however, they commence deducing results for higher temperatures, our experiments are not in accord; there being no indication of the carbon line crossing the platinum line, but only a very slight indication in one of the series of an approach above 230°.

Assuming the platinum line for our wire to be the same as that given in Tait's diagram (Fleeming Jenkin, p. 178) we get a diagram for carbon (fig. 8A), in which the line is fairly parallel to 250° C., after which it gradually increases its distance.

Other Changes in the Properties of the Body at the same Temperature.

This change in the thermo-electric power of carbon is accompanied by other changes. The resistance, the expansion, and the specific heat all appear to undergo a corresponding alteration.

Resistance.—Accurate measurements of the resistance of carbon at high temperatures are very difficult to obtain, owing to the changes that take place in the connexions. It is desirable, if possible,

that the whole rod should be exposed to the same temperature. If the rods are thick the changes in the contacts, even at ordinary temperatures, become great in proportion to the resistance of the rods; and if thin there is great danger of them being changed by the heat.

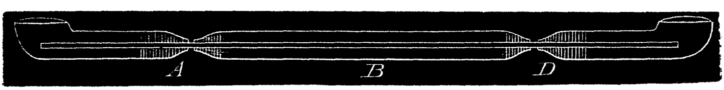
We found the method of electroplating with copper very good up to 500° or 600°, after which it completely broke down, and we were not able to get any other method to stand. Thus the experiments were stopped there, although we expected other changes at 800° to 1000°, from the numbers obtained for the specific heat by Weber.

The first method tried was that used by H. Muraska ('Annalen der Physik und Chemie,' vol. 13, 1881, p. 310), in which a hole is drilled in each end of the carbon rod, and after electroplating with copper, a copper rod is pushed in tight and brazed in. The objections to this method were: 1st, requires a thick rod; 2nd, better contact formed as the temperature rises, tending to produce error in the same direction as the results of the experiments.

Second. Forming a contact that would be liquid at all temperatures above 100°. This was done by drilling vertical holes near the ends of the rods, and filling them with fusible metal. Required thick rods, gave way.

Third. Used thin rods so that the change in contact resistance might not bear so large a proportion to that of the rod itself. Glass vessels shaped as in fig. 11 were prepared, and the rod packed at A

FIG. 11.

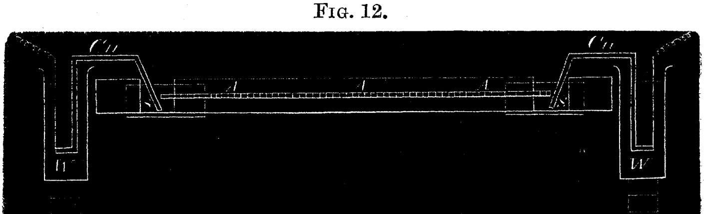


and B with asbestos. Fusible metal or solder was melted into the glasses, and the rod protected by a glass tube B.

Fourth. An attempt was made to form contacts by inserting the thin rod into cavities drilled into thick rods of carbon, and joining by Indian ink, sugar and graphite, &c.

Lastly, the rod was incased in thin sheet asbestos, well coated with wet clay between each layer. The ends were electroplated with copper and tinned. They projected beyond the asbestos covering

FIG. 12.



about $\frac{1}{2}$ inch. The glass tubes in the previous method were imitated in asbestos, and into the spaces S, S solder was melted, and thick copper wires inserted, the other ends of which were kept cool by water. When taking observations at high temperatures it is better to cover this with a glass tube at the portion AA. Out of a large series of readings we give four.

Graphite Rods.—These rods were supplied by Hogarth and Hayes of Keswick as pure natural Cumberland graphite.

Length, $7\frac{3}{4}$ inches; diameter, 0·155 inch.

Experiment 1.

Time of observation.	Temperature.	R. in ohms.
10	21°	42·3
12.15	600	23·8
12.25	412	29·7
12.50	278	33·72
3.35	21	42·3

Experiment 2.

11 A.M.	22°	30·4
12.50	155	27·0
2.55	202	26·2
4.30	278	25·5
5.54	390	23·2
Next day, 10.45	22	31·0

Carbon Rods.—Carbon rods supplied by Woodhouse and Rawson, Victoria Street, London. Very hard and good, 12 inches long; diameter, 0·22 inch.

Experiment 3.

Time of observation.	Temperature.	R. in ohms.
3.15 P.M.	347°	4·75
5	309	4·75
6.40	298	4·81
7.35	257	4·85
8	226	4·88
Next day 10 A.M.	23	5·2

Experiment 4.

12.15	325	4·74
2.30	273	4·83
4.10	221	4·90
5	202	4·93
Next day 11 A.M.	22	5·21

Changes per 1° C. per 1 ohm—

Expt. 1 gives—

21	
	0·0009
180	
	0·00068
278	
	0·00070
412	
	0·00076
600	

Expt. 2 gives—

22	
	0·0008
155	
	0·000678
202	
	0·00038
278	
	0·00052
391	

Expt. 3 gives—

23	
	0·00031
226	
	0·00025
257	
	0·000195
298	
	0·00032
347	

Expt. 4 gives

22	
	0·00031
221	
	0·00026
273	
	0·00030
325	

All showing a decrease (in the temperature coefficient) to about 250°, and then an increase.

This method cannot lay claim to absolute accuracy, as there is in some cases an increase of resistance by the change in the contact of copper with carbon, which appears when the rod cools as in Experiment 2. This, however, takes place at the higher temperatures, and tends to decrease the numbers obtained at those temperatures, and a correction, if one could be applied, would only increase the results obtained in the previous experiments.

Coefficient of Expansion.

Method.—As we wished to raise the rod to 500° or 600° C., it was impossible to expose the whole rod to that temperature, and at the same time to read the changes of position of a mark or point at the end of it with a microscope; nor did it appear probable that contact could be made by rods of other materials.

It was decided, therefore, to heat the central portion of a rod, keeping the end portions cold. We had thus one hot portion, two colder, and two others at a constant temperature. A rod, about 36 inches in length and ½ inch in diameter, was used. One end was electroplated and then soldered into a cavity in a brass rod which was firmly clamped to a vertical iron one fixed to a stone table. Into a small hole in the other end a fine needle was fixed whose change of position was read by a microscope.

The central portion of the carbon was covered with a thin coating of clay, then with paper to consume the oxygen, outside that a glass tube packed with asbestos inside of a porcelain tube.

Ten inches of the centre of this was heated in a gas furnace. The temperature was taken with a platinum thermometer (fig. 5), EF giving the temperature of the hottest part, AB and CD those of the portions between the hottest and the constantly cold portion.

EF was 10 inches, AB and CD 7 inches each, total 24 inches. Outside the rod was kept cool with water.

In calculating the portion of the expansion due to the parts AB and CD the numbers obtained in Experiment 4 are used. The expansion is assumed to be regular up to 143°, the number obtained from this is used for the cooler portions AB and CD up to 98°; above that, the number found in the same experiment for the expansion between 143° and 263° is used.

One example will show what is meant. In Experiment 4, observation 1, we have—

$$\left.\begin{array}{ll} \text{AB} \;\ldots\ldots & 54^\circ \\ \text{CD} \;\ldots\ldots & 29 \\ \text{EF} \;\ldots\ldots & 143 \\ \text{Cold portion} & 15 \end{array}\right\} \quad \begin{array}{rcl} 54-15 = & 39\times 7 & = 273 \\ 29-15 = & 14\times 7 & = 98 \\ 143-15 = & 128\times 10 & = 1280 \\ & & \overline{1651} \end{array}$$

$$\frac{0\cdot0075}{1651} = 0\cdot0000045.$$

Table showing the Temperature of each Portion of the Rod at each Observation, the total Change in Length, and the Coefficient of Expansion.

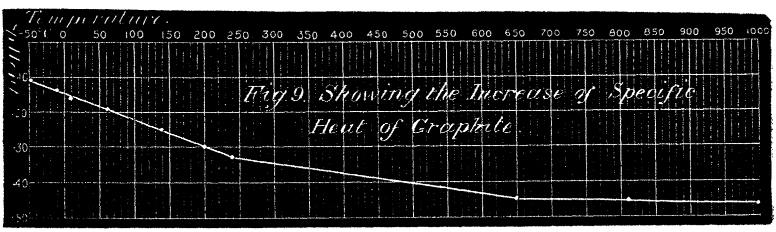
AB.		EF.	CD.	Cold part.	Total expansion.	Coefficient of expansion.
					in.	
Expt. 1.	180°	614°	263°	13°	0·057083	0·00000666 between 13° and 614°
„ 2.	208	645	263	14	0·059375	0·0000066 „ 14 „ 645
„ 3.	101	300	89	15	0·021041	0·0000056 „ 15 „ 300
	208	645	167	15	0·058541	0·000008 „ 300 „ 645
Expt. 4.	54	143	29	15	0·0075	0·0000045 „ 15 „ 143
	86	263	44	15	0·0183′	0·0000077 „ 143 „ 263
	98	282	49	15	0·0216′	0·0000140 „ 263 „ 282
	194	602	167	15	0·0583′	0·000009 „ 282 „ 602

Nos. 1 and 2 give the average of the whole of No. 4, and part 1 of No. 3 is not far removed from the average of parts 1 and 2 of 4, while part 2 of No. 3 is lower than the number obtained in No. 4.

Specific Heat.—H. F. Weber gives the following numbers as the specific heat of carbon at various temperatures; unfortunately for our purpose, no observations are recorded between 250° and 640°.

	Temperature.	Specific heat.	Rate of change per 1° C.
	−50·3°	0·1138	0·00075
Graphite	−10·7	0·1437	0·00076
	61·3	0·1990	0·00071
	138·5	0·2542	0·00067
	201·6	0·2966	0·00063
	249·3	0·3250	0·00030
	641·9	0·4454	0·000045
	822	0·4539	0·000083
	977	0·467	

The curve, fig. 9, is plotted from these numbers and shows a fairly regular increase in the specific heat with the temperature up to 250° where the line bends; another bend occurs at 650°.



Other changes were looked for at the higher temperature, but the contacts gave way, and no definite results were obtained. In conclusion I wish to acknowledge my obligations to Professor J. J. Thomson, F.R.S. and to R. T. Glazebrook, F.R.S., for much information and advice during the whole course of the work.

Summary of Results.

	Below 250° C.	Above 250° C.
A. Effect of contact of hot and cold carbon.	Current from cold to hot.	Current from hot to cold.
B. Thermo-electric line	Rises.	Falls.
C. Rate of decrease of resistance per degree per ohm.	Diminishes.	Increases.
D. The rate of increase of the coefficient of expansion.	Increases.	Decreases.
E. Rate of increase of the specific heat.	Fairly regular.	Falls to half.

FIG. 1.

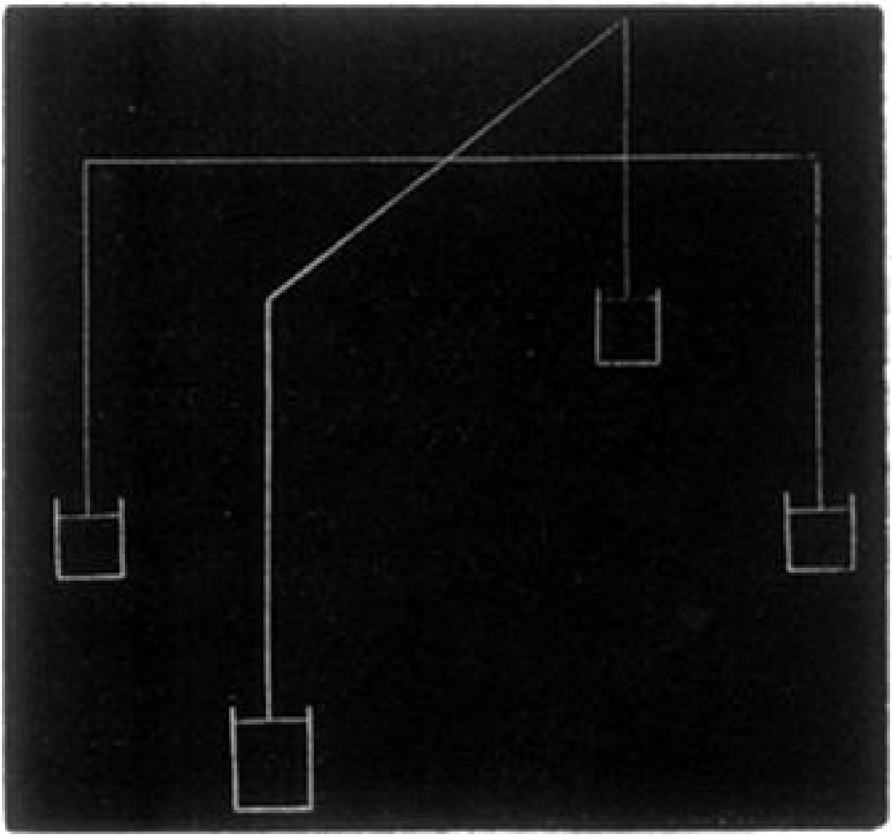


FIG. 2.

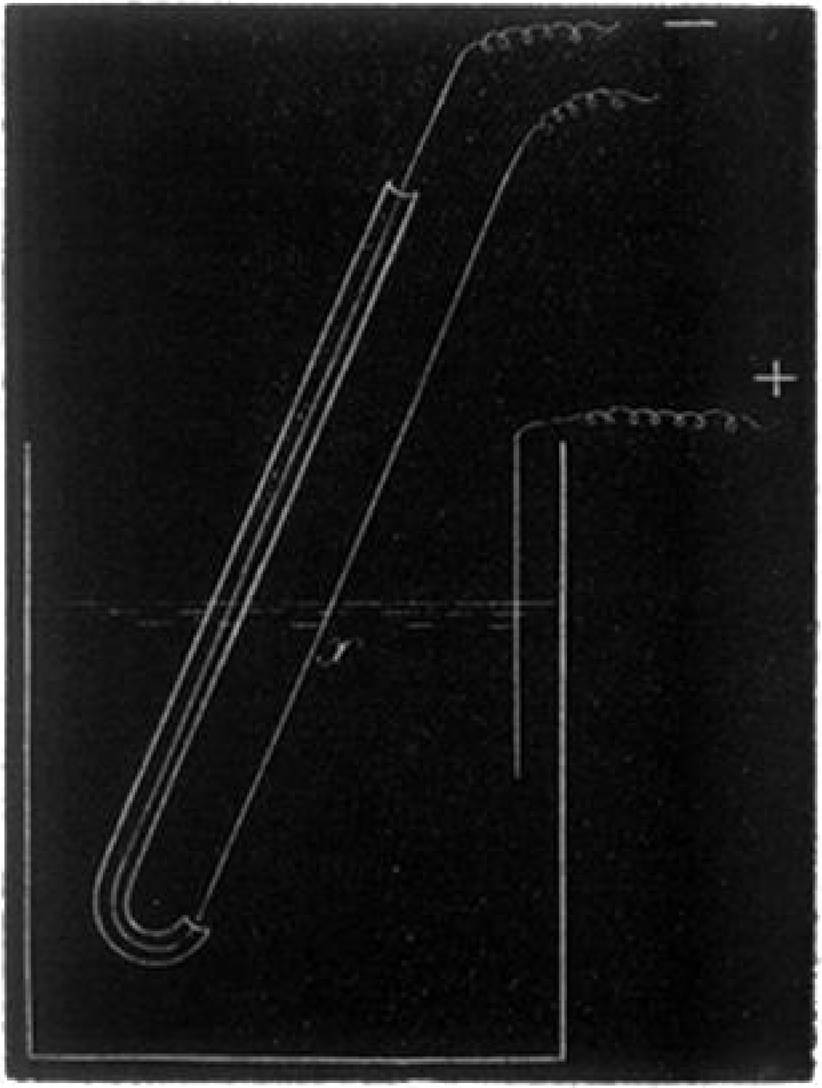


Fig. 3.

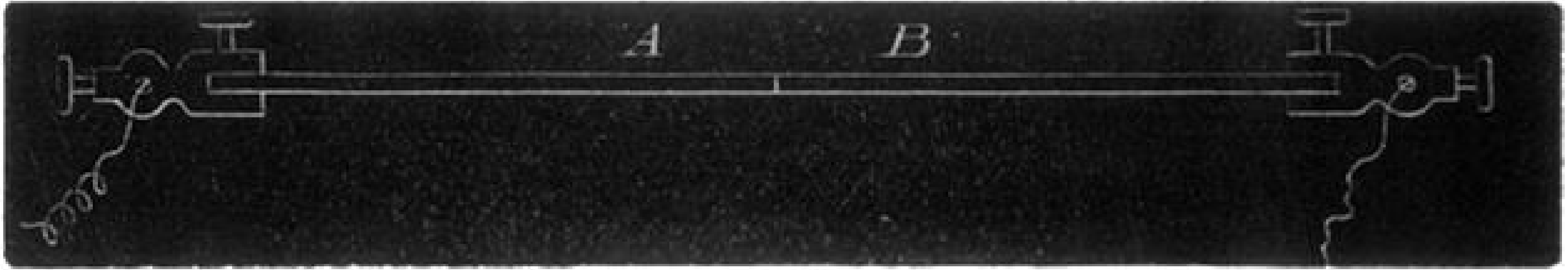


FIG. 4.

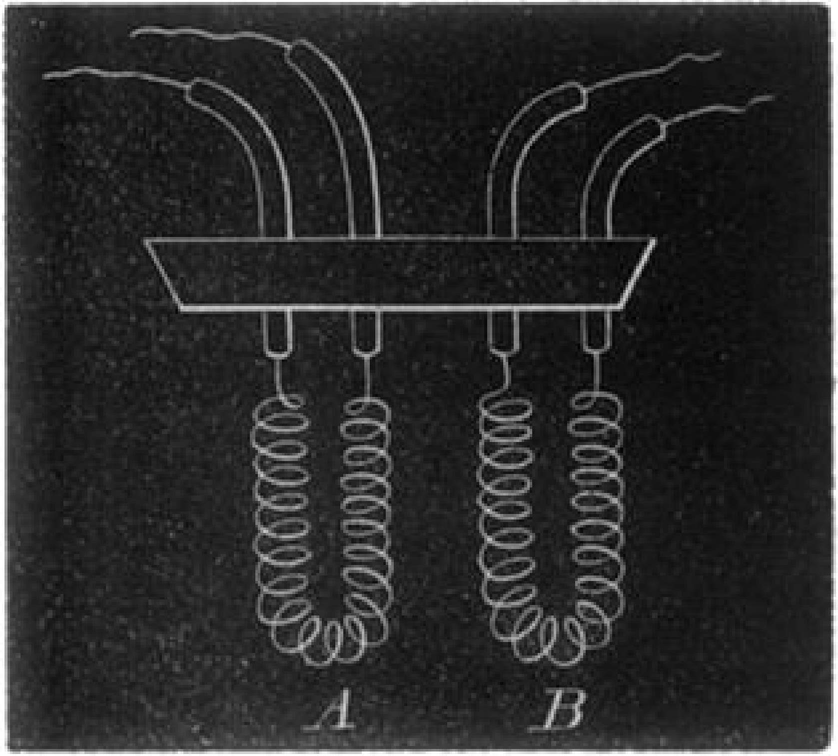


FIG. 5.

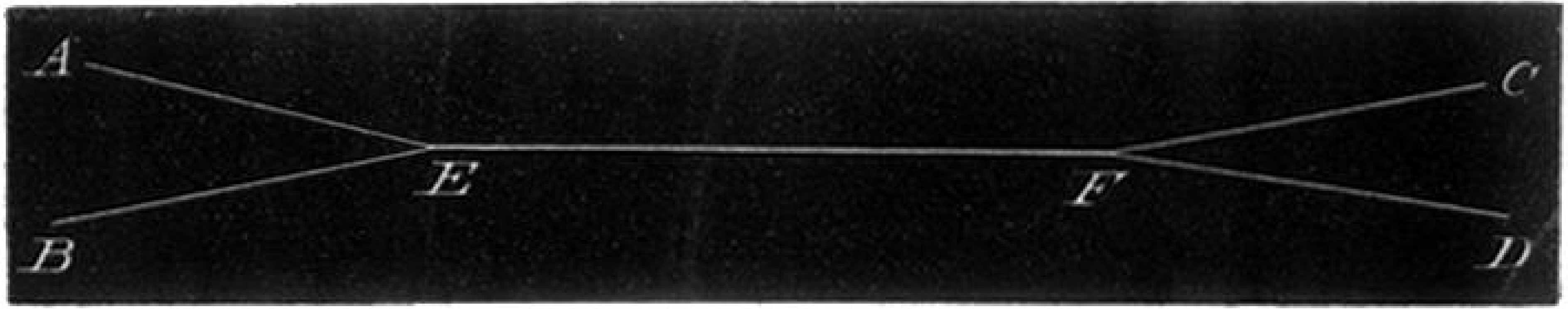


Fig. 6.

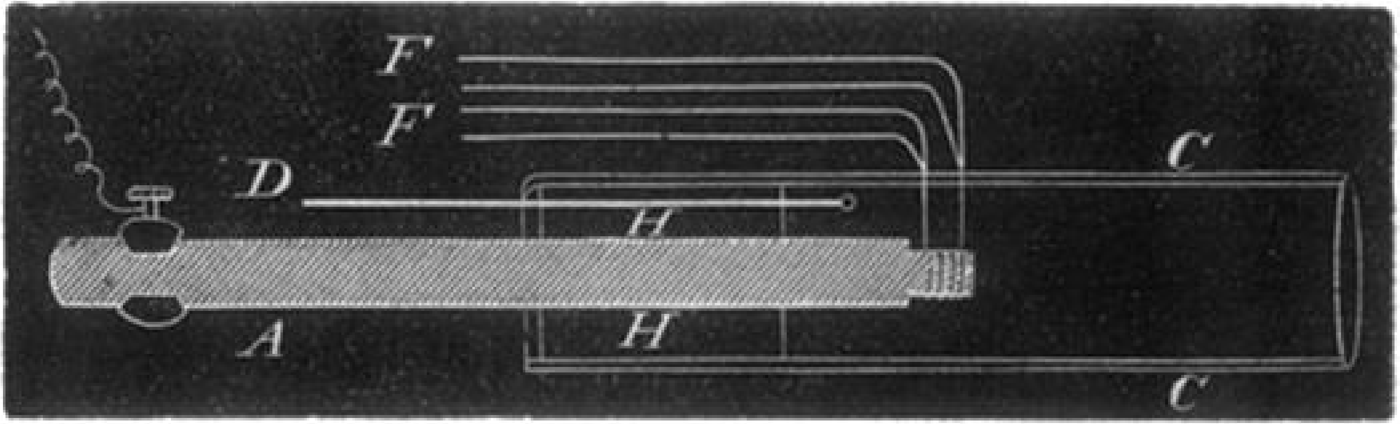
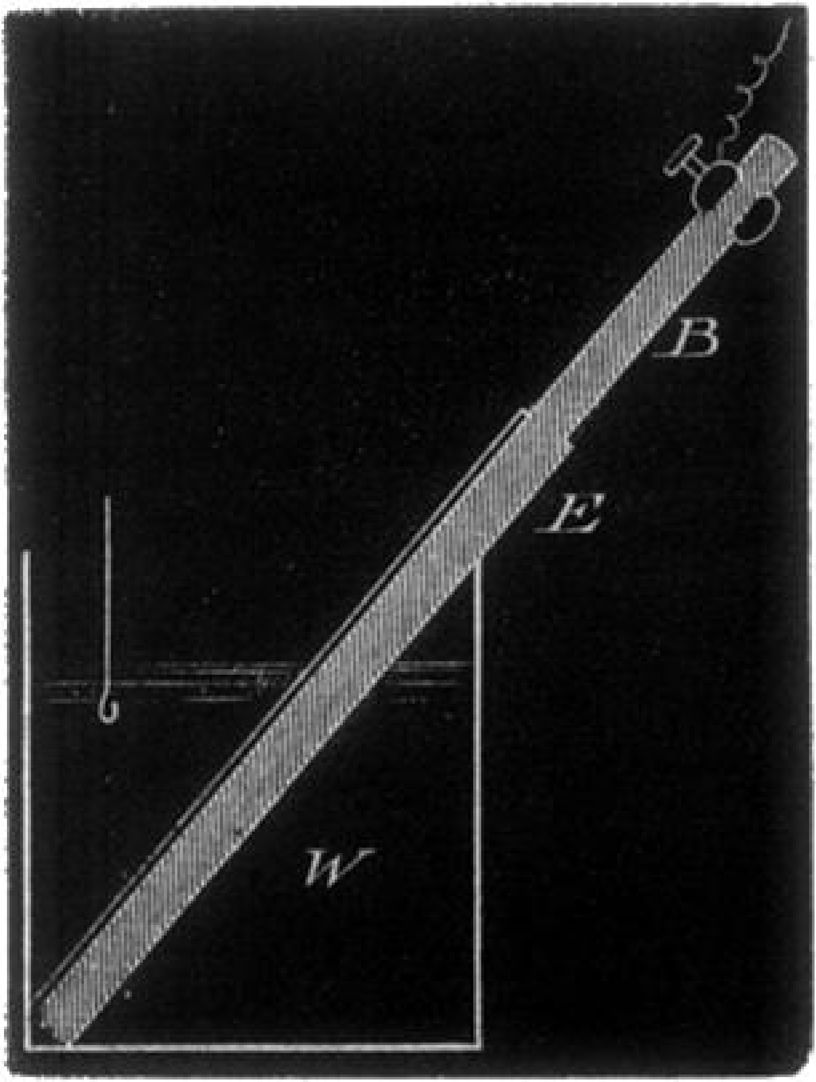


FIG. 6a.



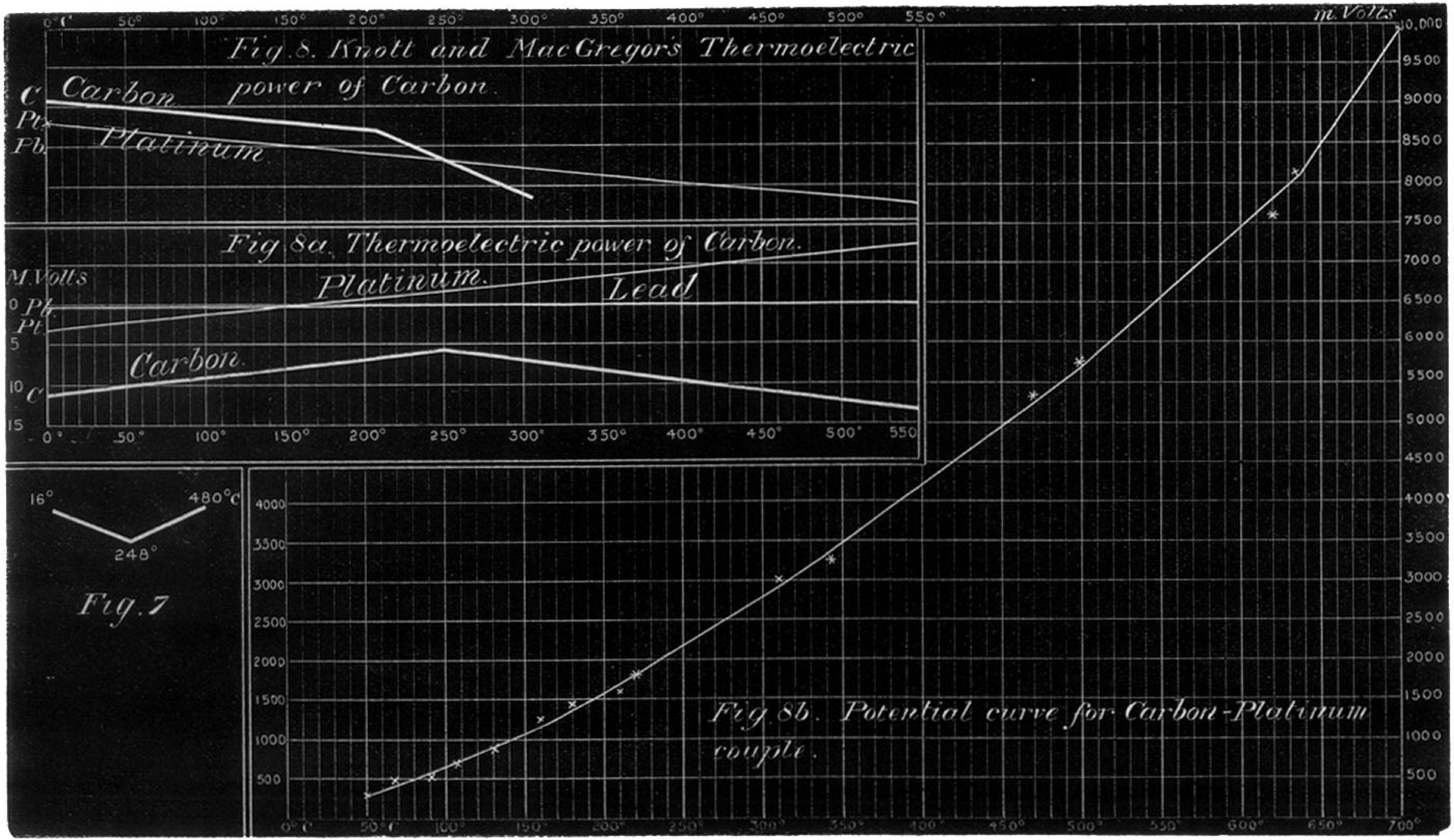


Fig. 8. Knott and MacGregor's Thermoelectric power of Carbon.

Fig 8a. Thermoelectric power of Carbon.

Fig. 7

Fig 8b. Potential curve for Carbon-Platinum couple.

FIG. 10.

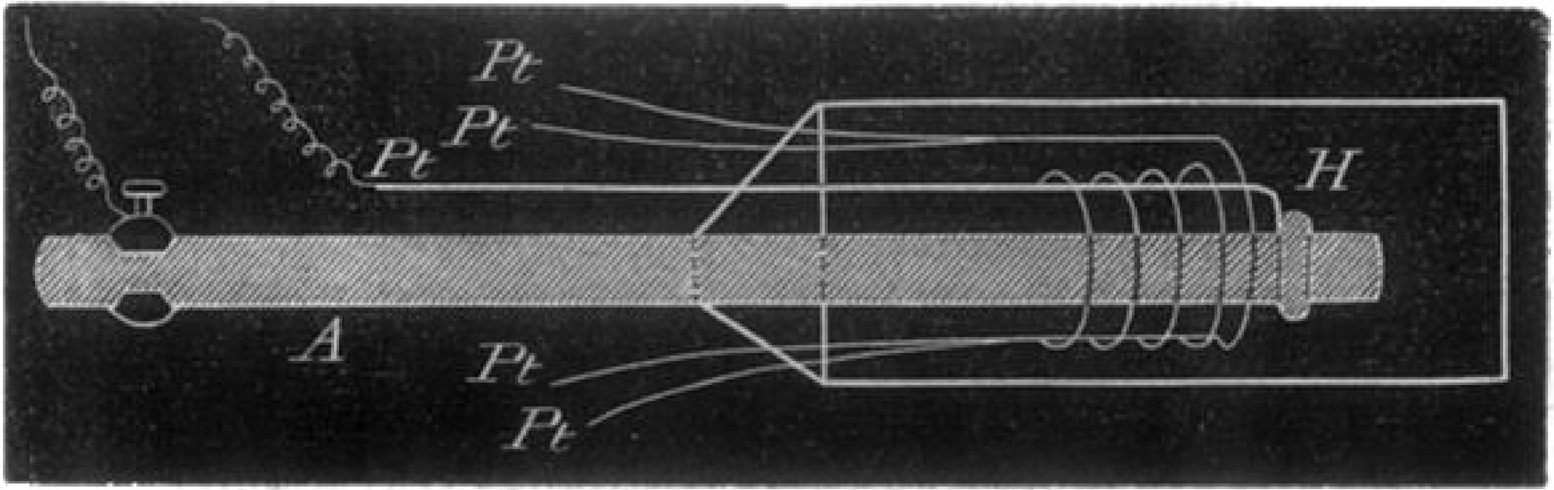


FIG. 11.

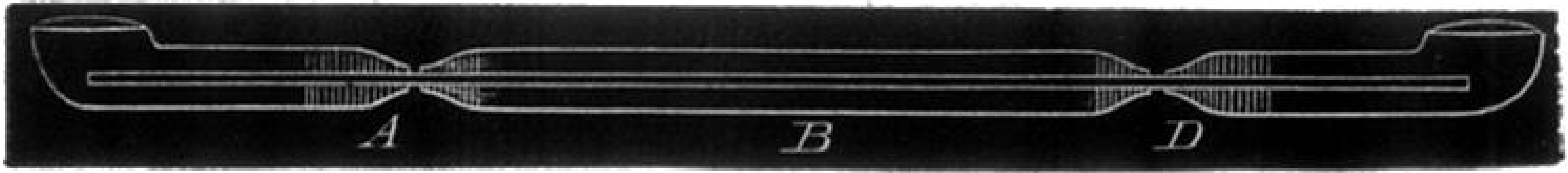
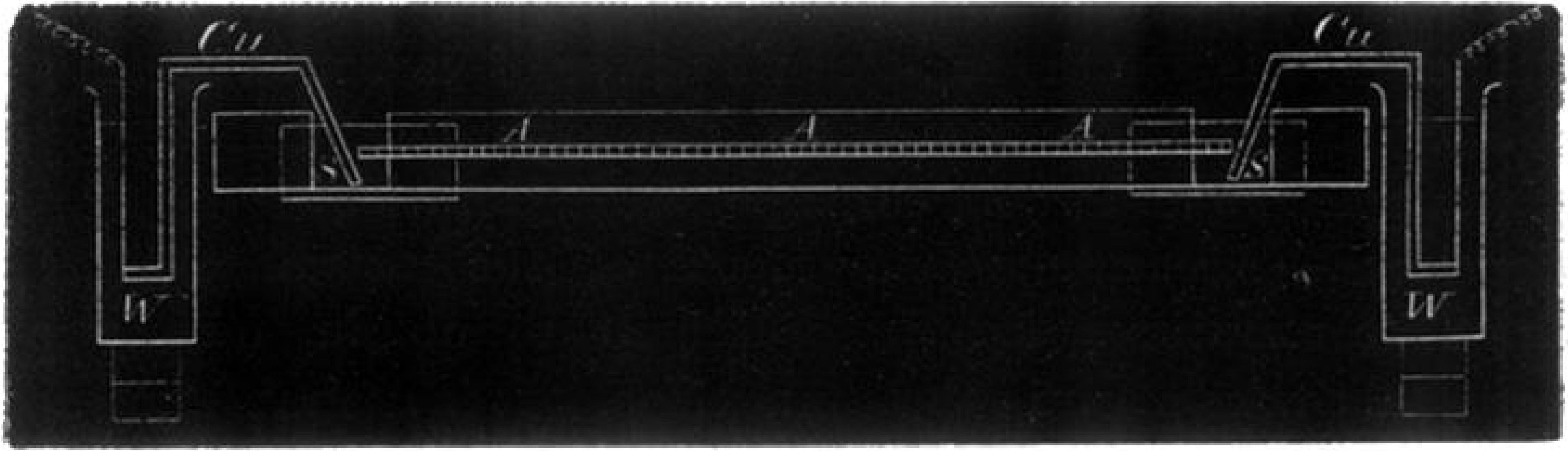


FIG. 12.



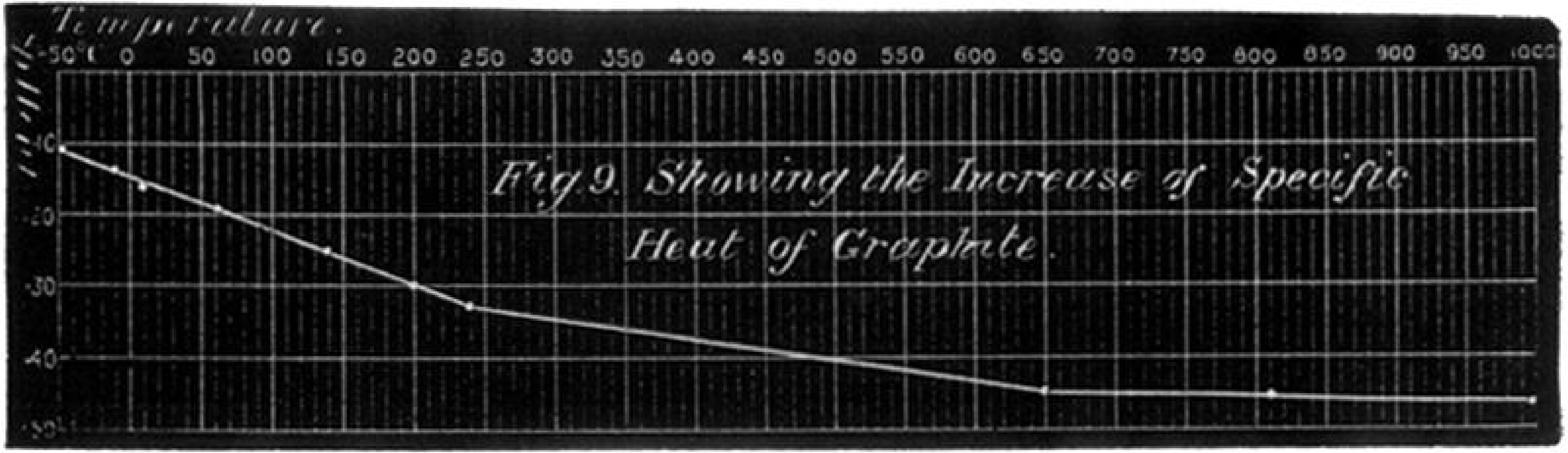


Fig. 9. Showing the Increase of Specific Heat of Graphite.